Climate Forecasting or the Continuous Adaptation to Climate Change

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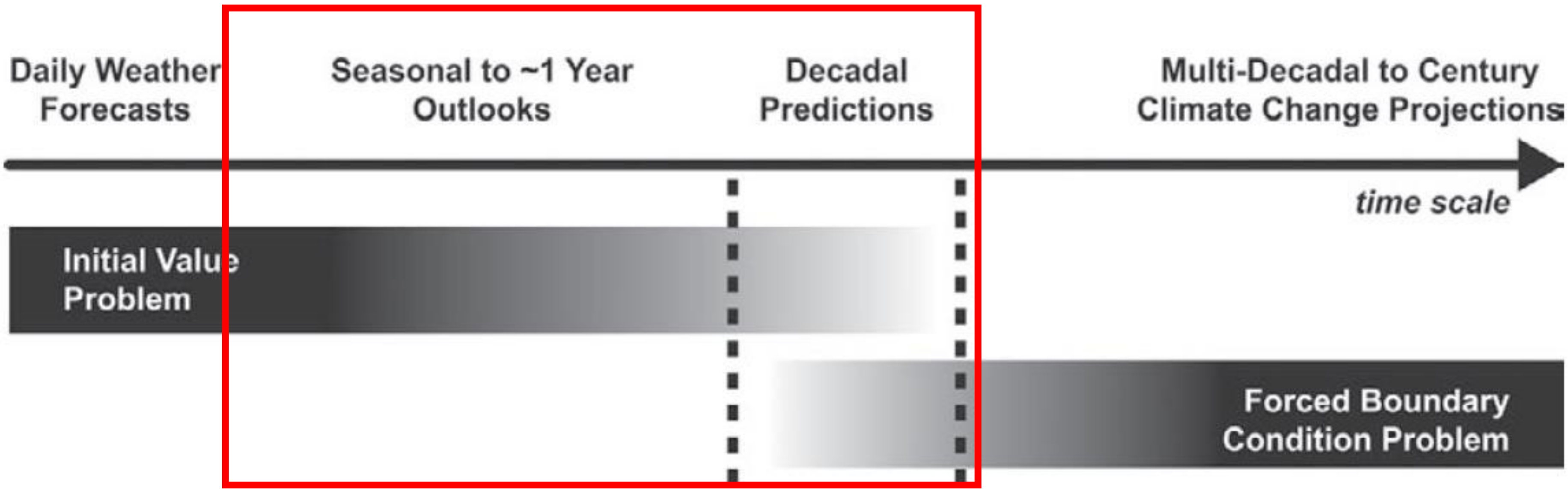
Climate time scales

Progression from initial-value problems with weather forecasting at one end and multi-decadal to century projections as a forced boundary condition problem at the other, with climate prediction (sub-seasonal, seasonal and decadal) in the middle. Prediction involves initialization and systematic comparison with a simultaneous reference.



Meehl et al. (2009)

Sources of seasonal predictability

- Important:
    - o ENSO - biggest single signal
    - o Other tropical ocean SST - difficult
    - o Climate change - important in mid-latitudes
    - o Local land surface conditions - soil moisture, snow
    - o Atmospheric composition - difficult

- Other factors:
    - o Volcanic eruptions - important for large events
    - o Mid-latitude ocean temperatures - still somewhat controversial
    - o Remote soil moisture/snow cover - not well established
    - o Sea-ice anomalies - at least local effects
    - o Stratospheric influences - various possibilities
    - o Remote tropical atmospheric teleconnections

- Unknown or Unexpected

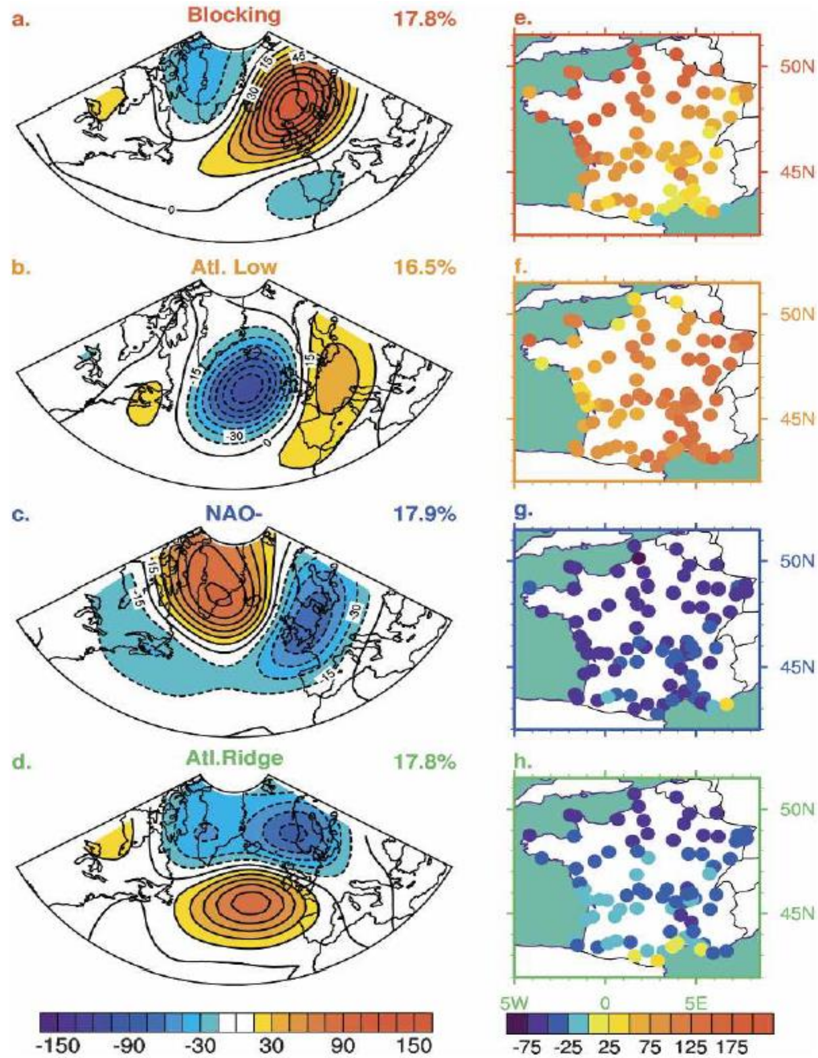
Methods of seasonal forecasting

- Empirical forecasting
  - Use past observational record and statistical methods
  - Works with reality instead of error-prone numerical models ✓
  - Limited number of past cases ✘
  - A non-stationary climate is problematic ✘
  - Can be used as a benchmark ✓

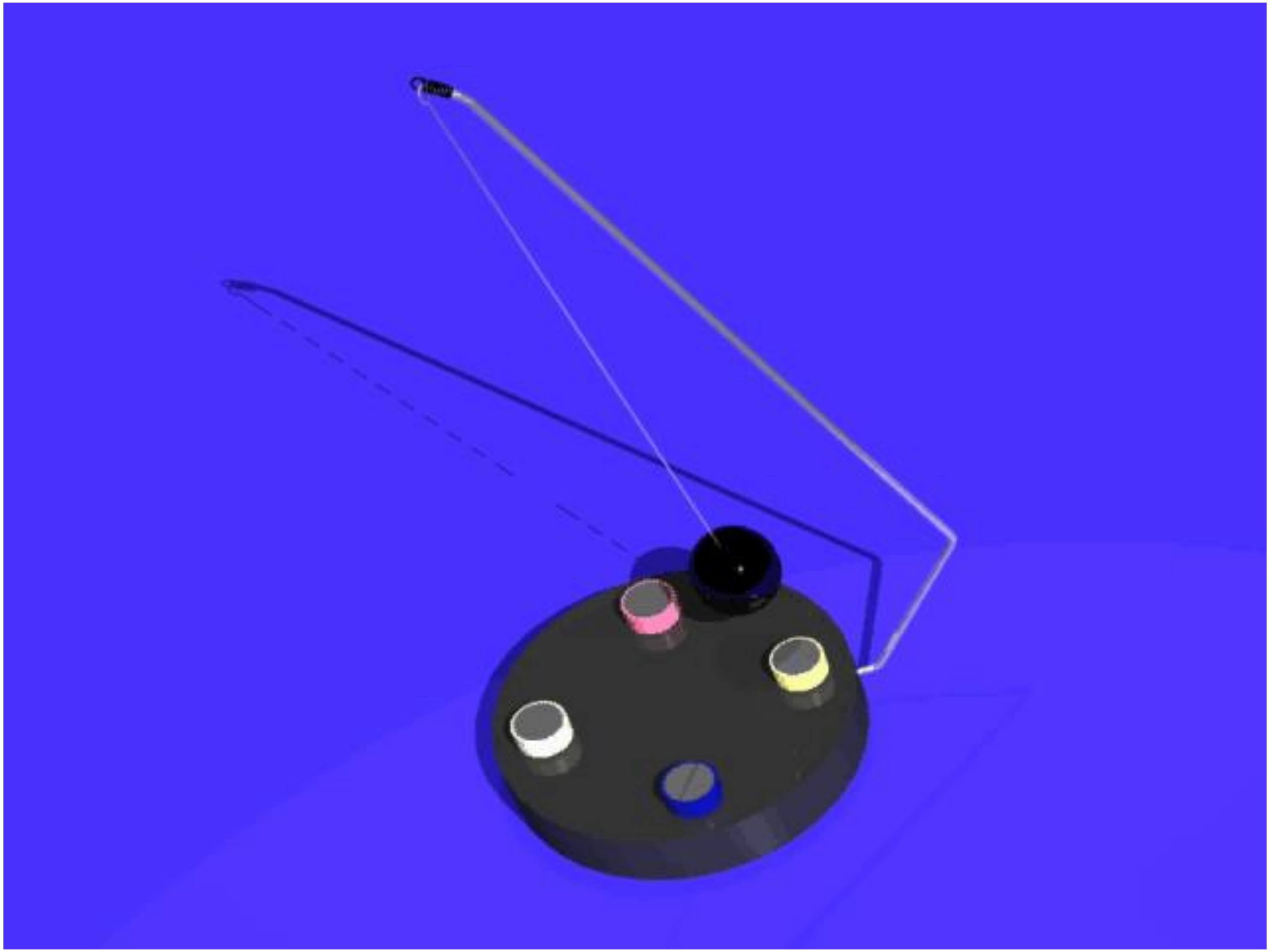
- Single-tier GCM forecasts
  - Include comprehensive range of sources of predictability ✓
  - Predict joint evolution of ocean and atmosphere flow ✓
  - Includes a large range of physical processes ✓
  - Includes uncertainty sources, important for prob. Forecasts ✓
  - Systematic model error is an issue! ✘

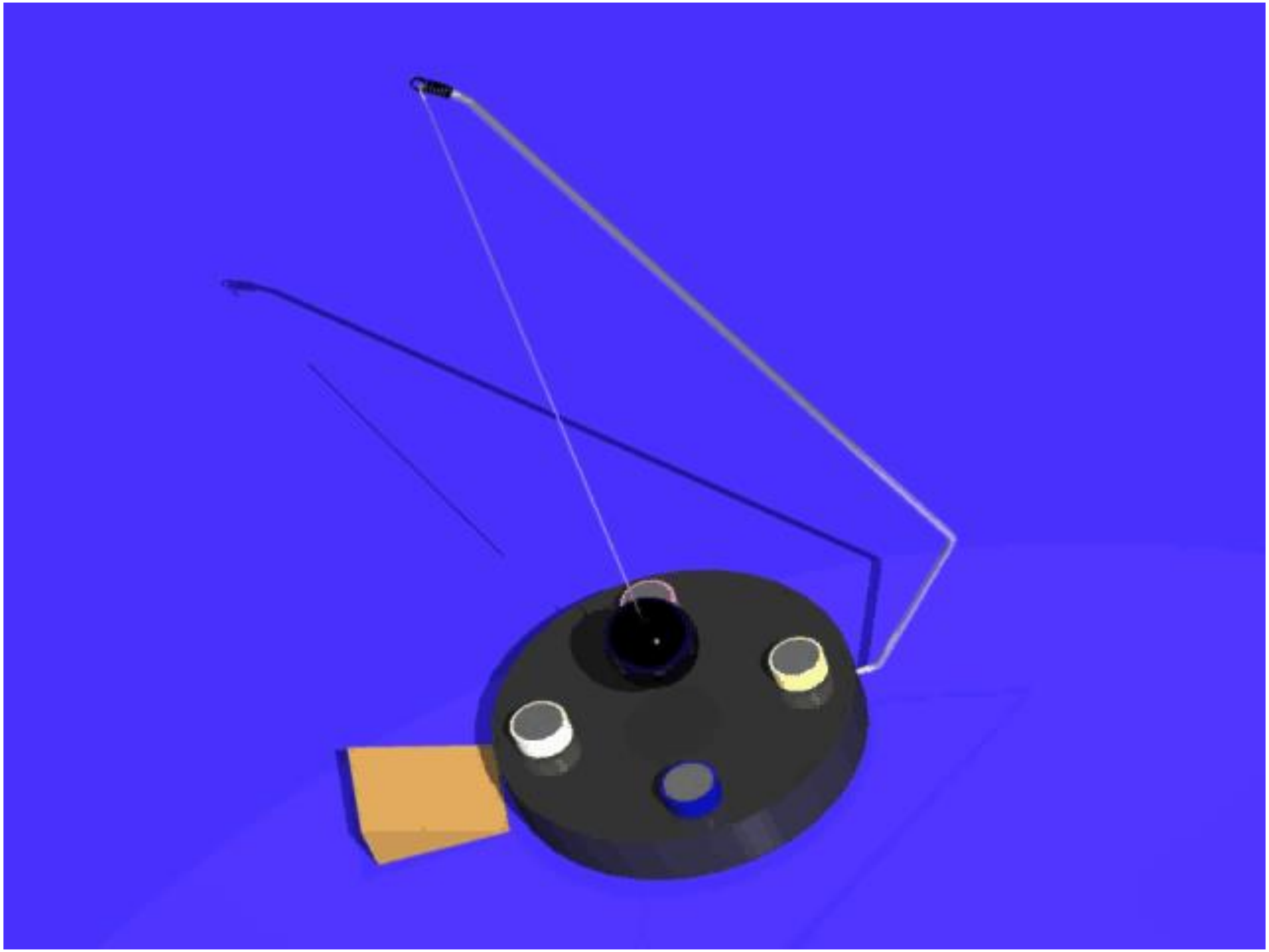
A simile: Weather types

Z500 summer weather types and frequency change (%) of warm days

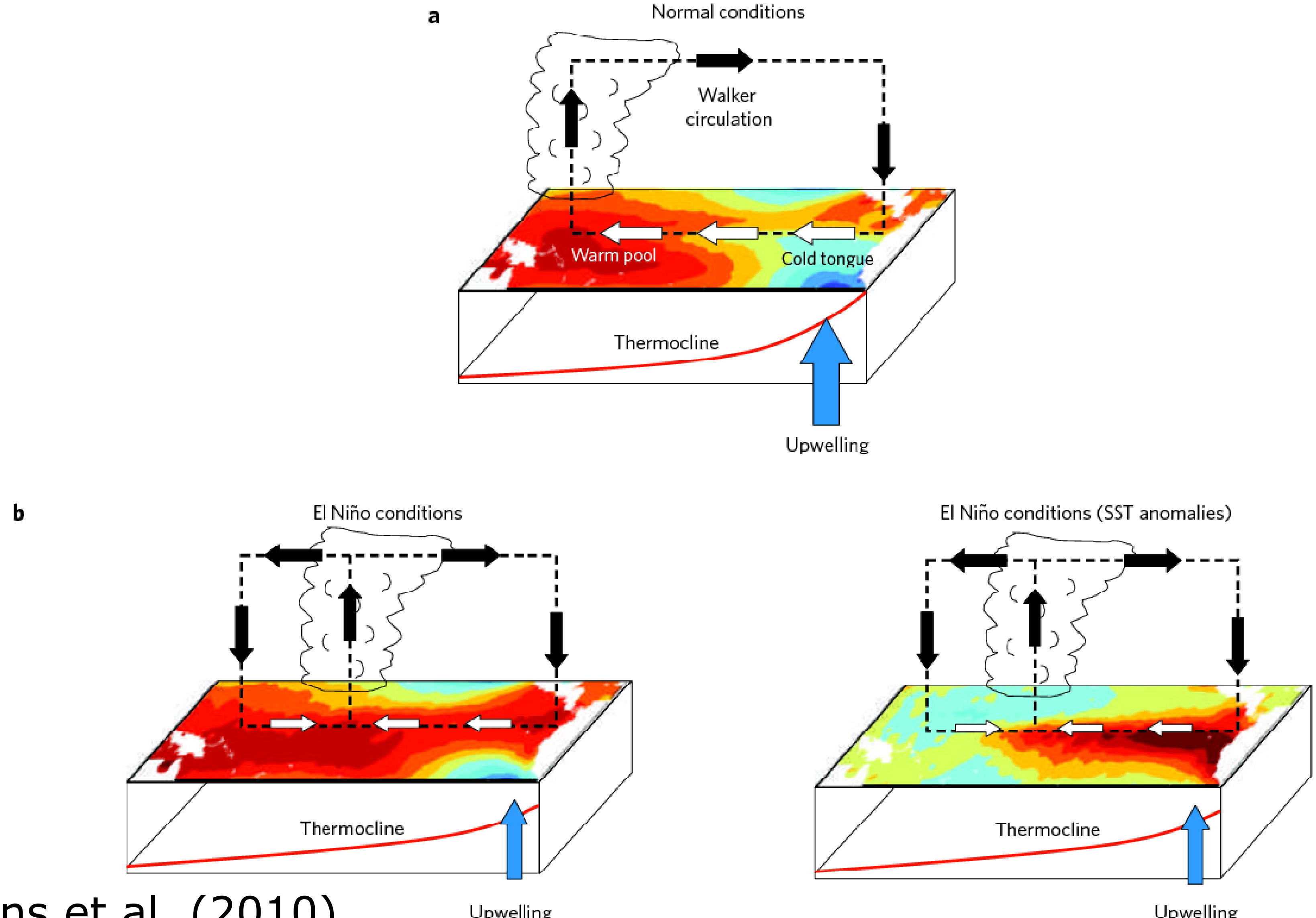


Cassou et al. (2005)





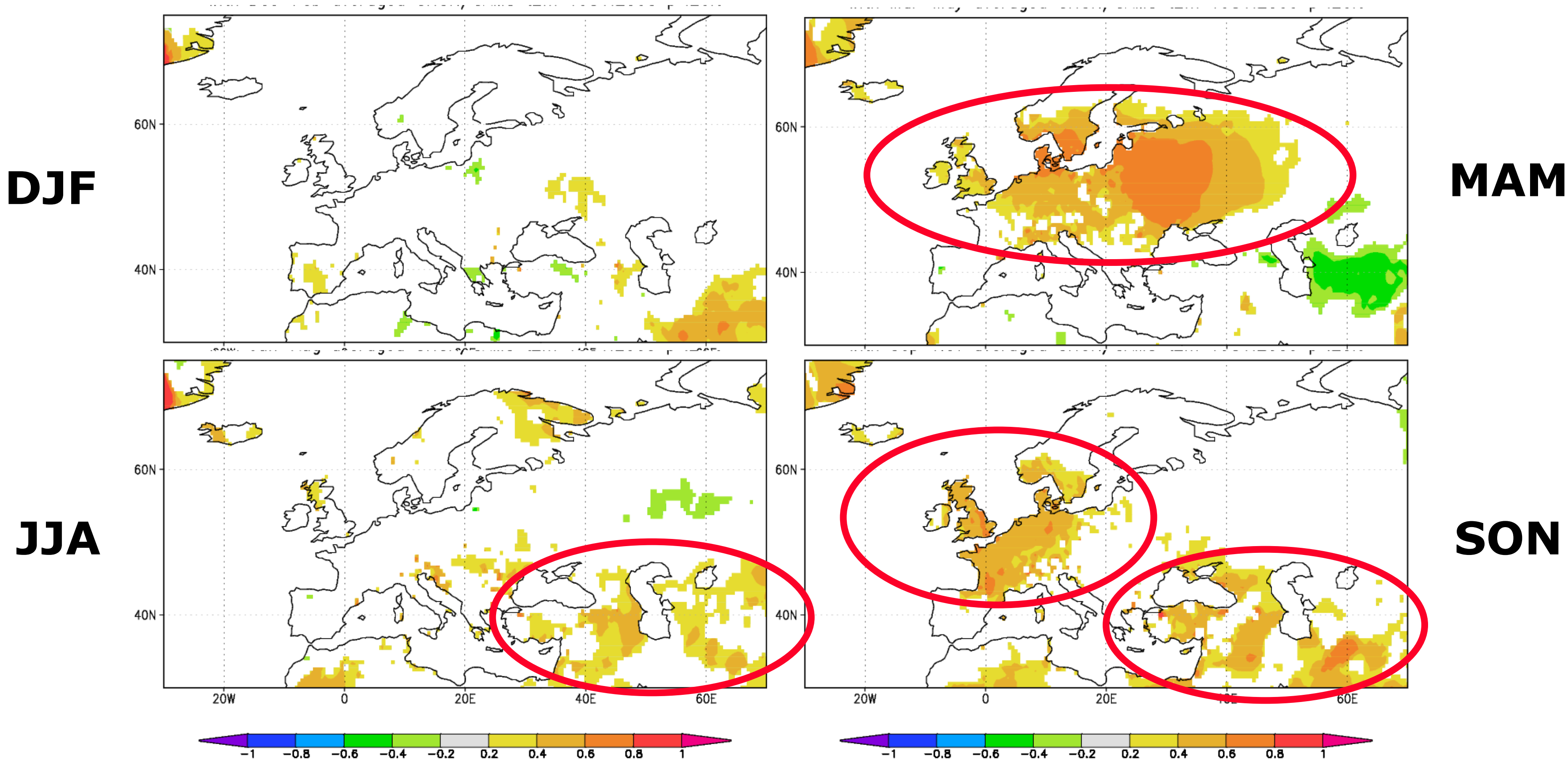
The wedge: ENSO in the tropical Pacific



Collins et al. (2010)

Temperature skill: persistence

Correlation of GHCN temperature of one-month lead anomaly persistence over 1981-2005. Only values statistically significant with 80% confidence are plotted.

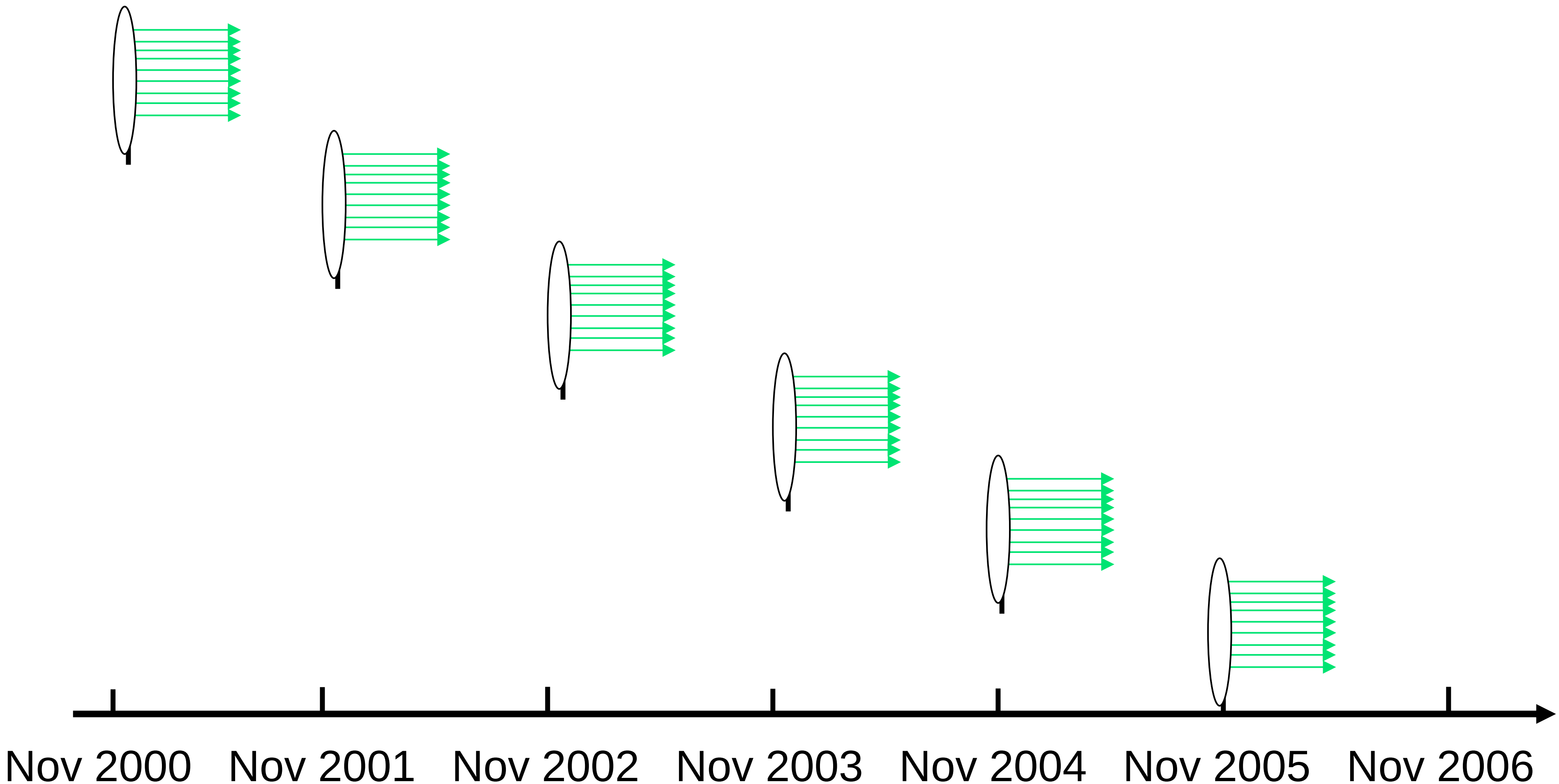


To produce dynamical forecasts

- Build a coupled model
- Prepare initial conditions
- Initialize coupled system
    - The aim is to start the system close to reality. Accurate SST is particularly important, plus ocean sub-surface. Usually, worry about "imbalances" a posteriori.
- Run an ensemble forecast
    - Explicitly generate an ensemble on the e.g. 1st of each month, with perturbations to represent the uncertainty *in the initial conditions*; run forecasts for several months.
- Produce probability forecasts from the ensemble
- Apply calibration and combination if significant improvement is found, for which hindcasts are required

Ensemble initialized climate predictions

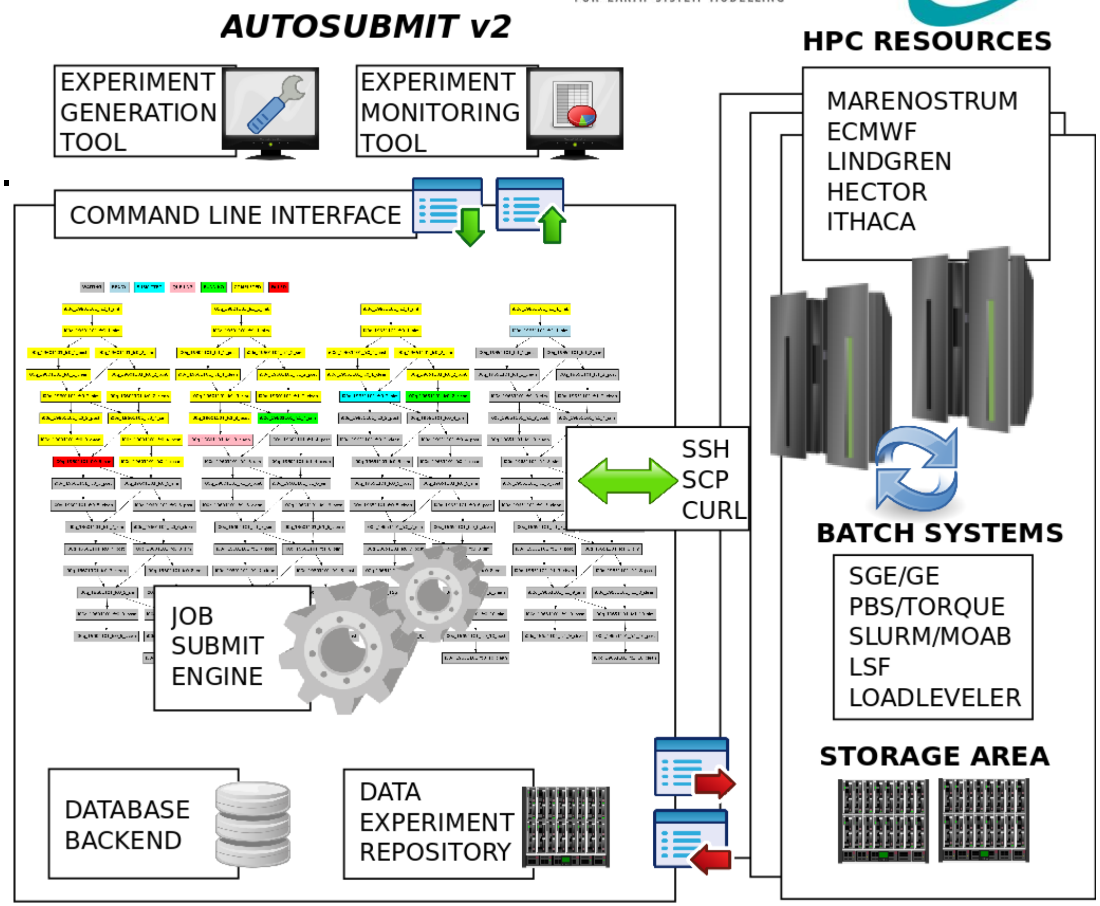
Assume an ensemble forecast system with an initialized ESM



Autosubmit

Autosubmit acts as a wrapper to run a climate experiment on a HPC. The experiment is a sequence of jobs that it submits, manages and monitors. When a job is complete, the next one can be executed.

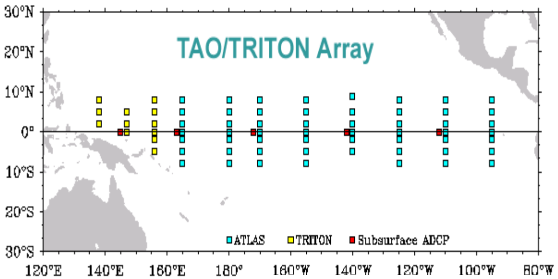
- Divided in 3 phases: ExpID assign, experiment creation, run.
- Separation experiment/autosubmit codes.
- Config files for autosubmit and experiment.
- Database to store experiment information.
- Common templates for all platforms.
- Recovery after crashes.
- Dealing with a list of schedulers and communication protocols.

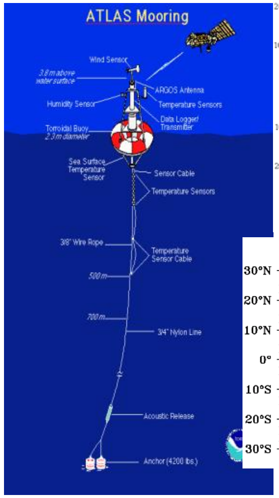


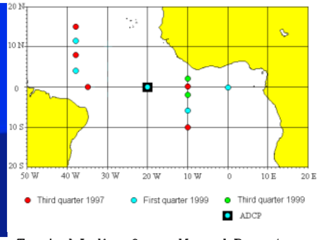
Each job has a colour in the monitoring tool: yellow=completed, green=running, blue=pending, etc.

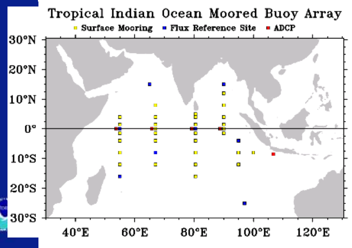
Real-time ocean observations

Moorings

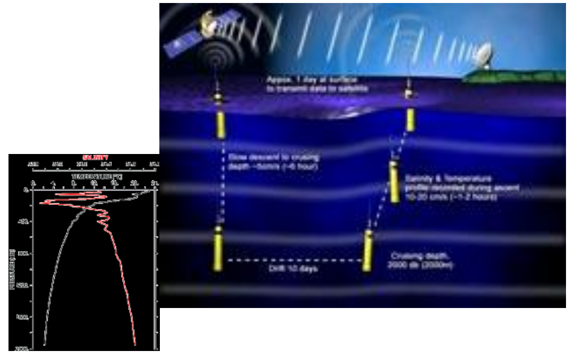


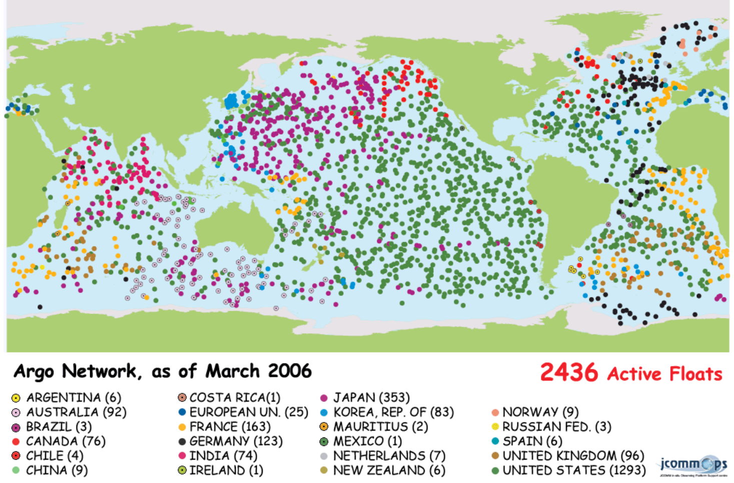






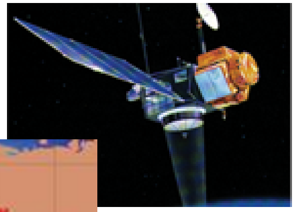
ARGO floats

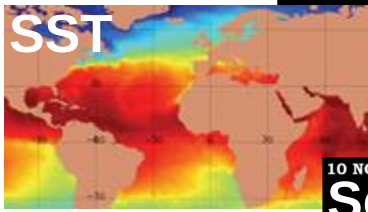


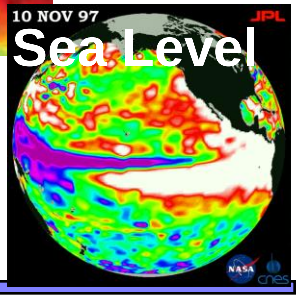


XBT (eXpendable BathiThermograph)

Satellite

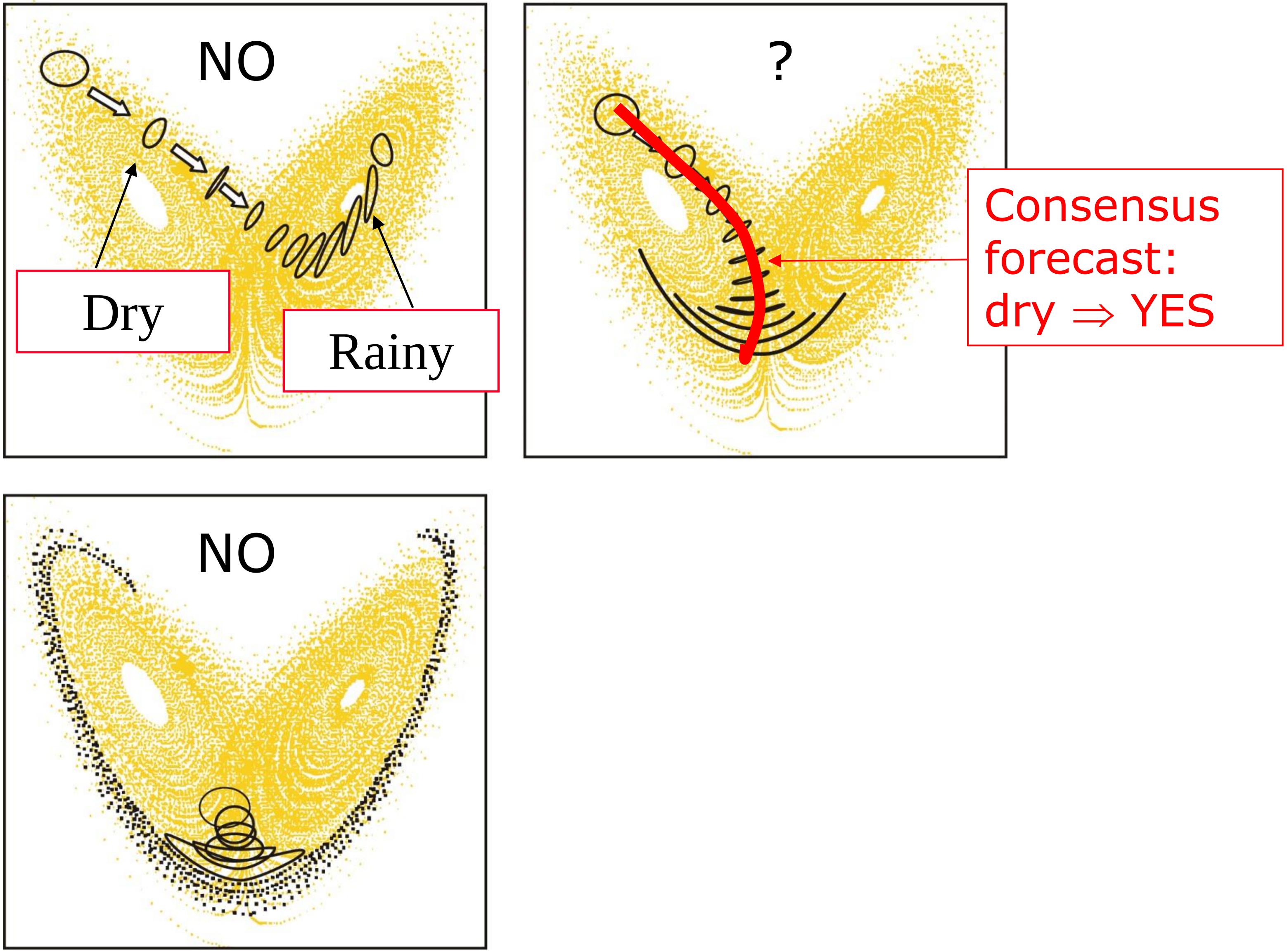






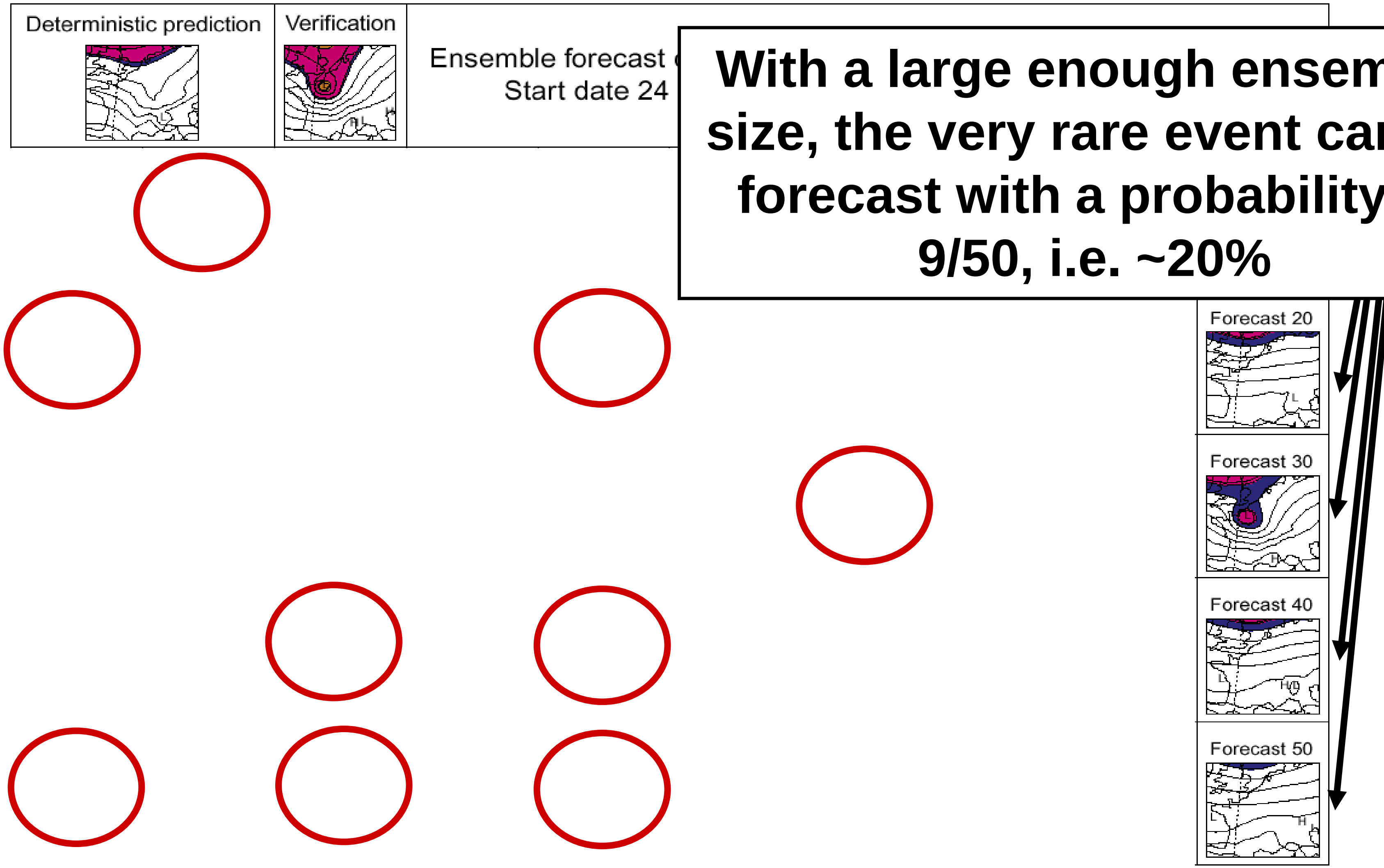
Why running several forecasts

A farmer is planning to spray a crop tomorrow



How many members: ensemble size

ECMWF forecasts (D+42) for the storm Lothar



With a large enough ensemble size, the very rare event can be forecast with a probability of 9/50, i.e. ~20%

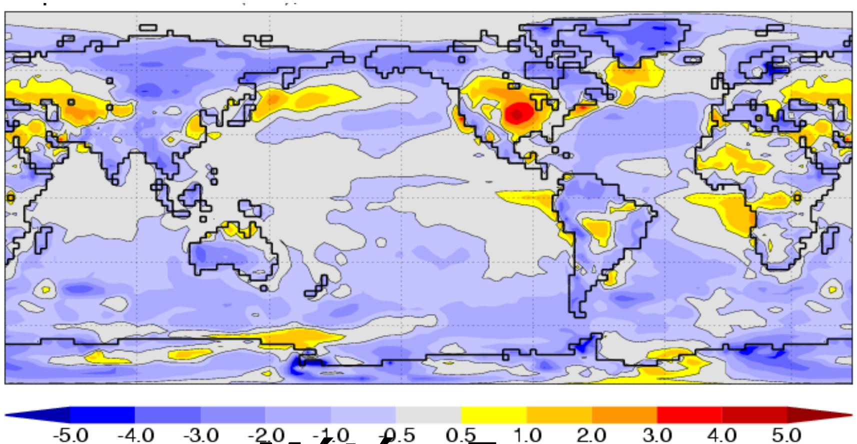
And there are systematic errors

- Model drift is typically comparable to signal
  - Both SST and atmosphere fields
- Forecasts are made *relative* to past model integrations
  - Model climate estimated from 25 years of forecasts (1981-2005), all of which use a 11 member ensemble. Thus the climate has 275 members.
  - Model climate has both a mean and a distribution, allowing us to estimate eg tercile boundaries.
  - Model climate is a function of start date and forecast lead time.
- Implicit assumption of linearity
  - We implicitly assume that a shift in the model forecast relative to the model climate corresponds to the expected shift in a true forecast relative to the true climate, despite differences between model and true climate.
  - Most of the time, the assumption seems to work pretty well. But not always.

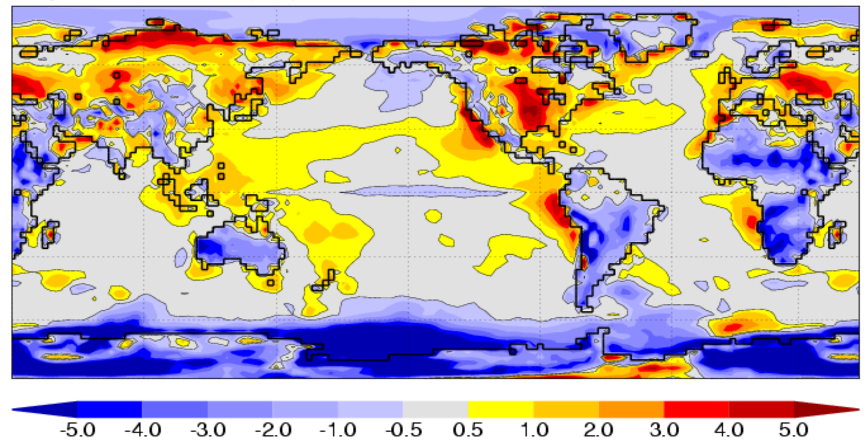
Mean error

Mean biases (JJA 2mT over 1993-2005) are often comparable in magnitude to the anomalies which we seek to predict

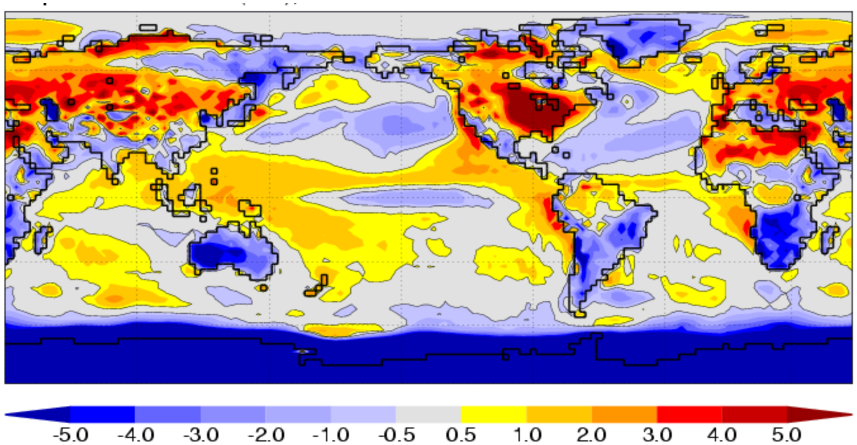
ECMWF



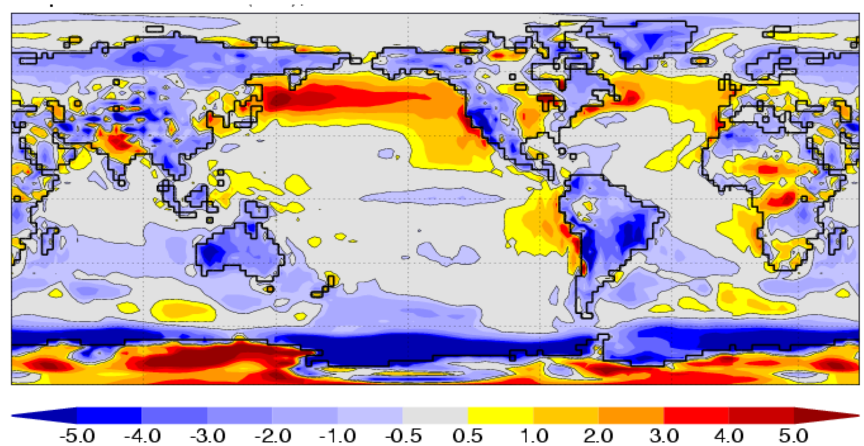
Met Office



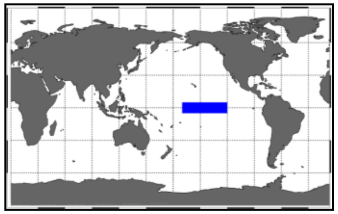
Météo-France

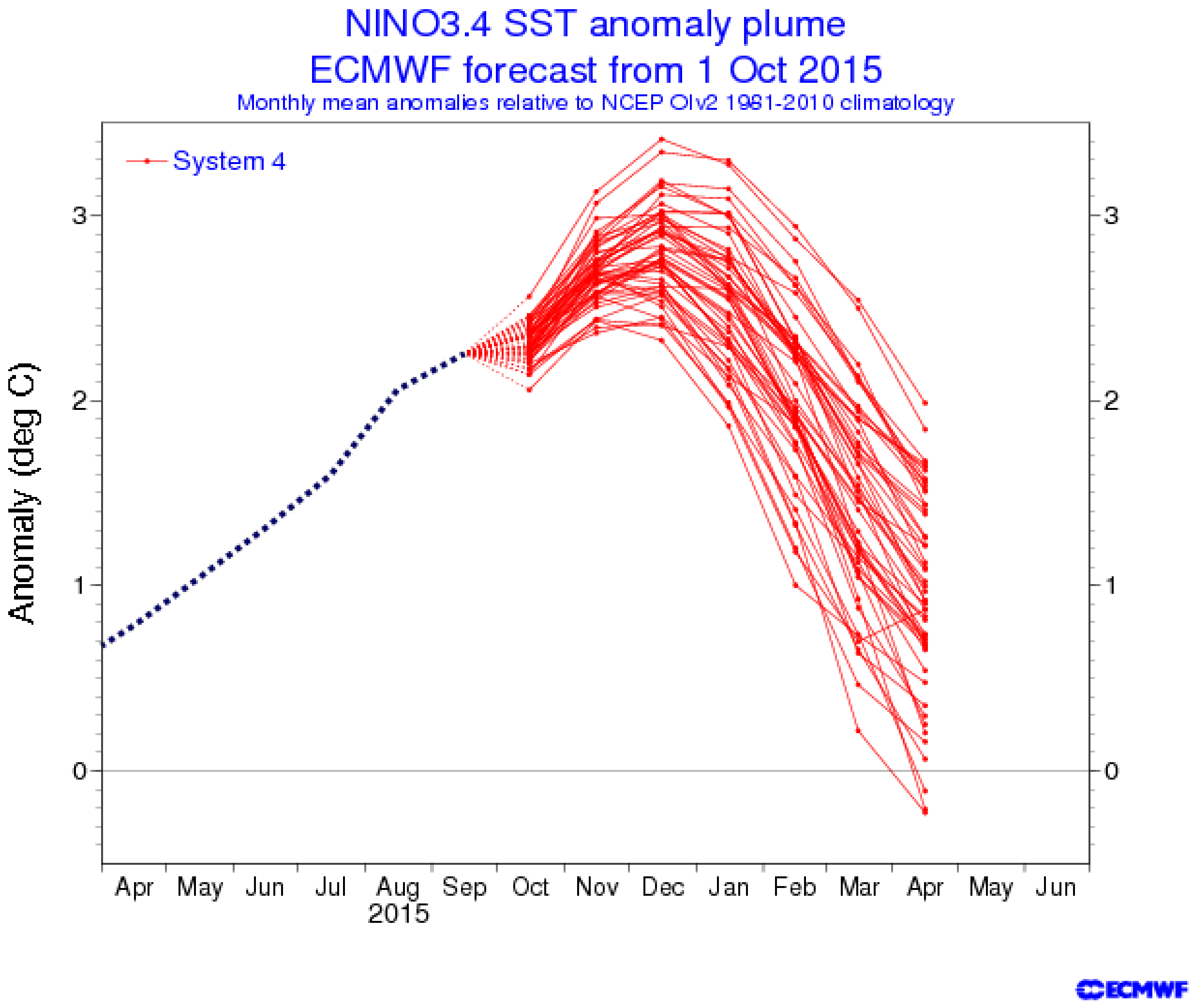


CFS



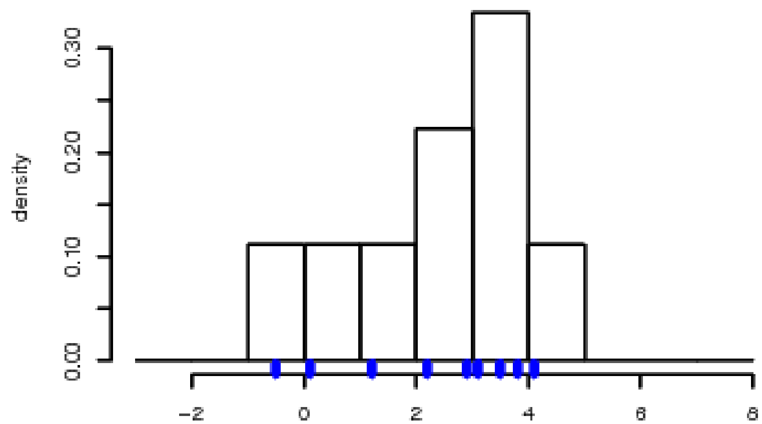
ENSO ensemble predictions

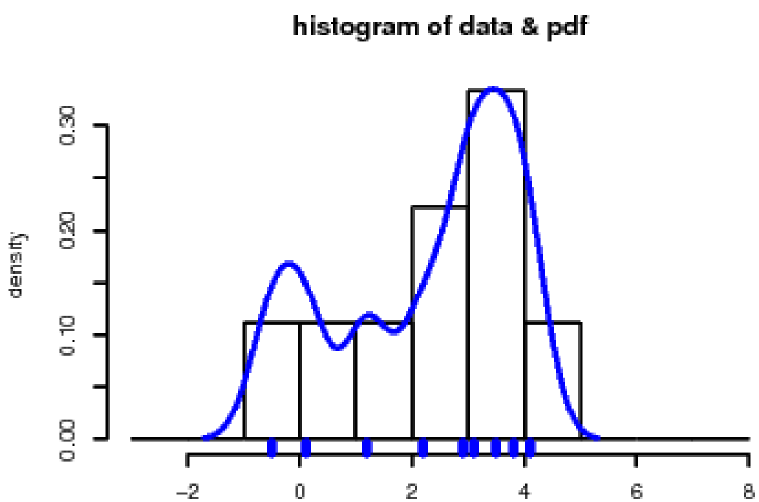


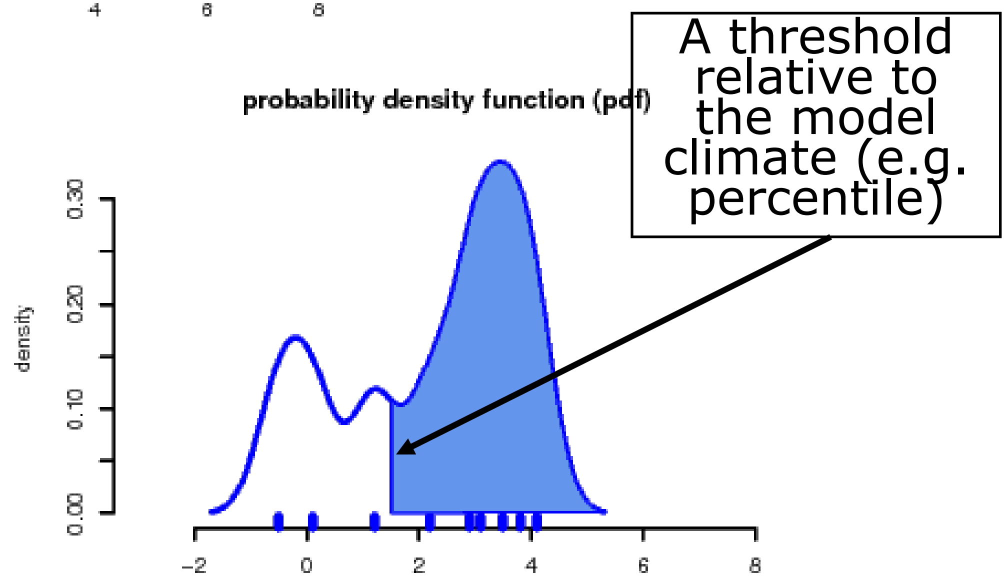


From ensembles to probability forecasts

Constructing a probability forecast from a nine-member ensemble







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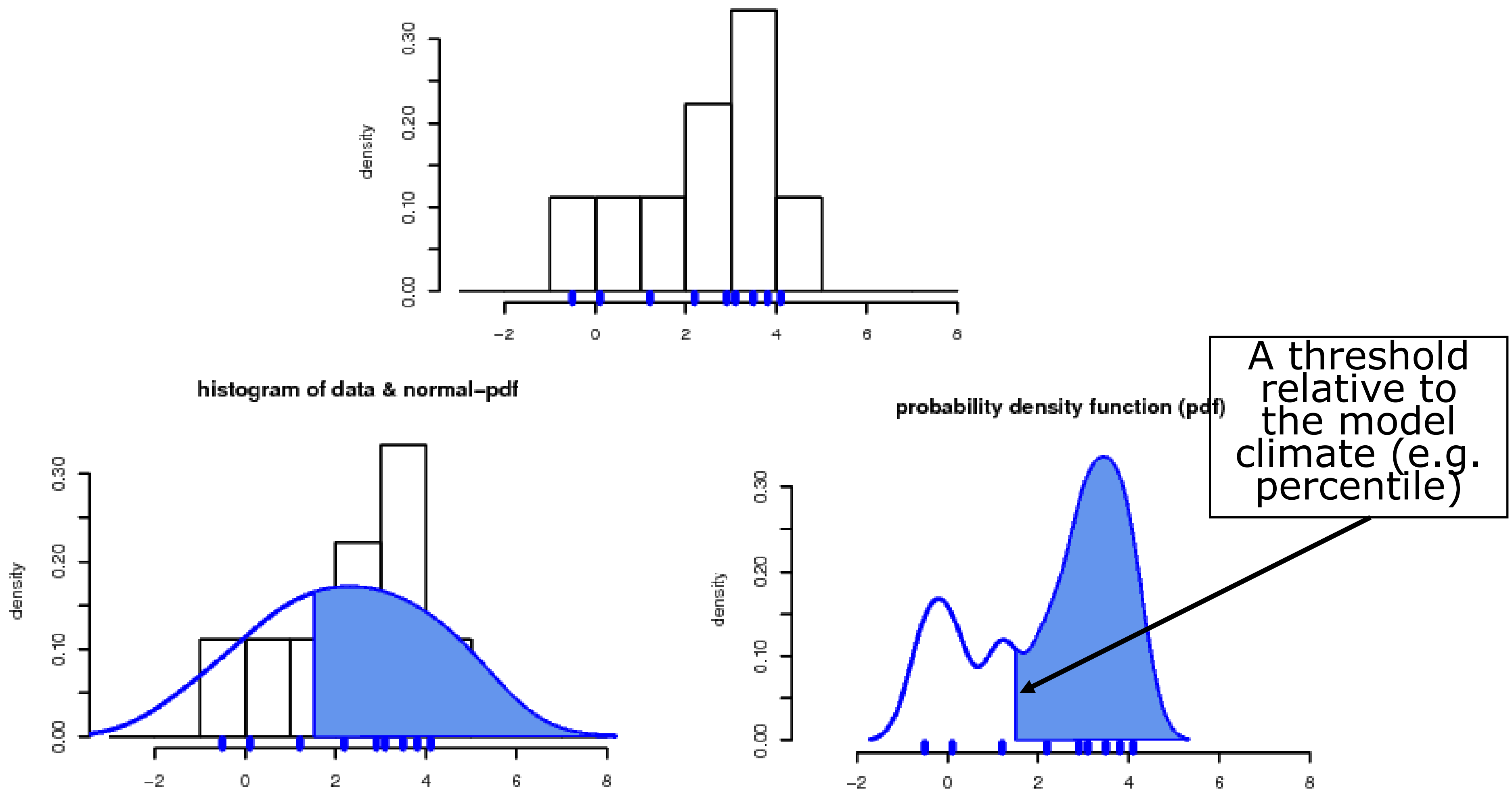
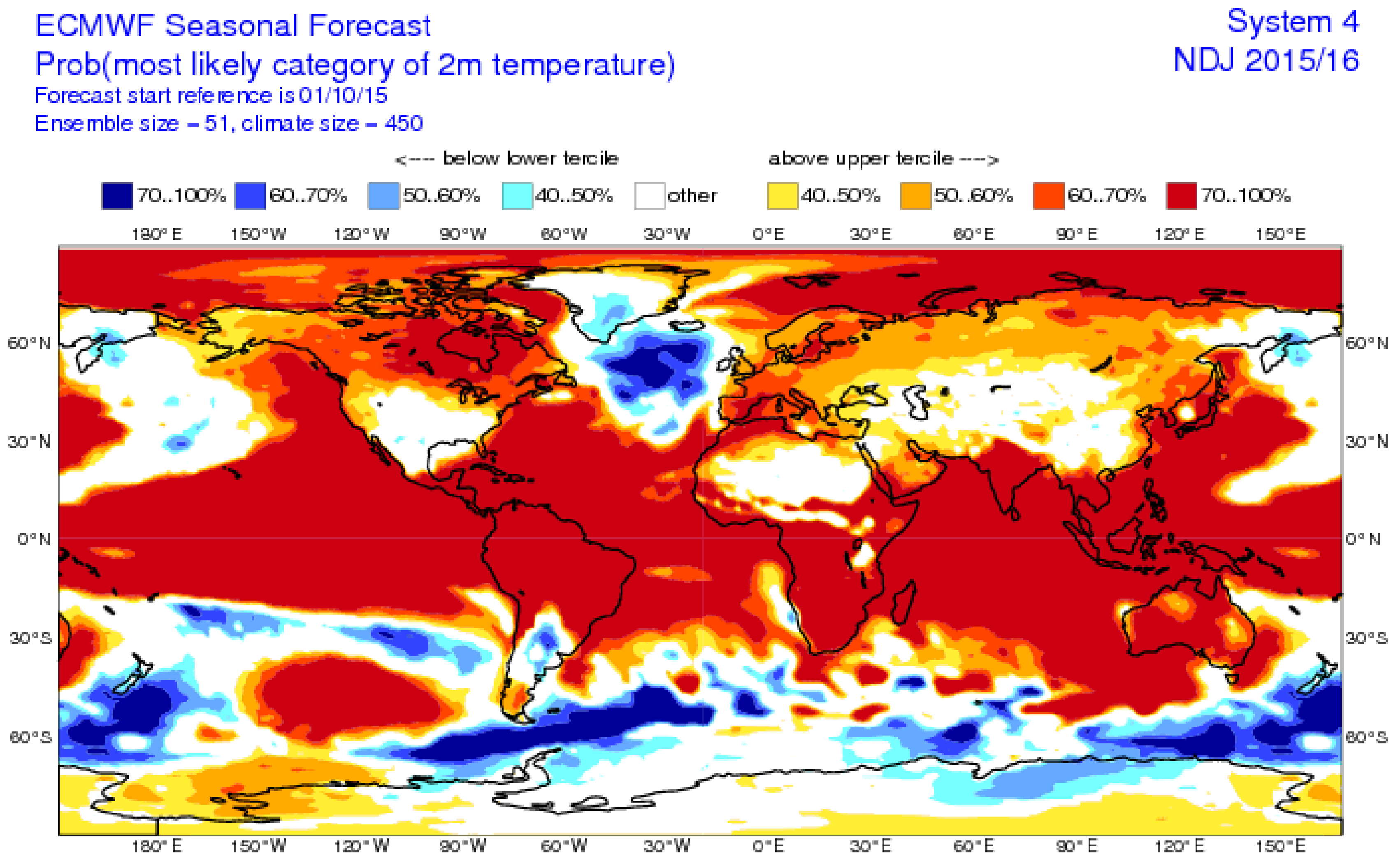
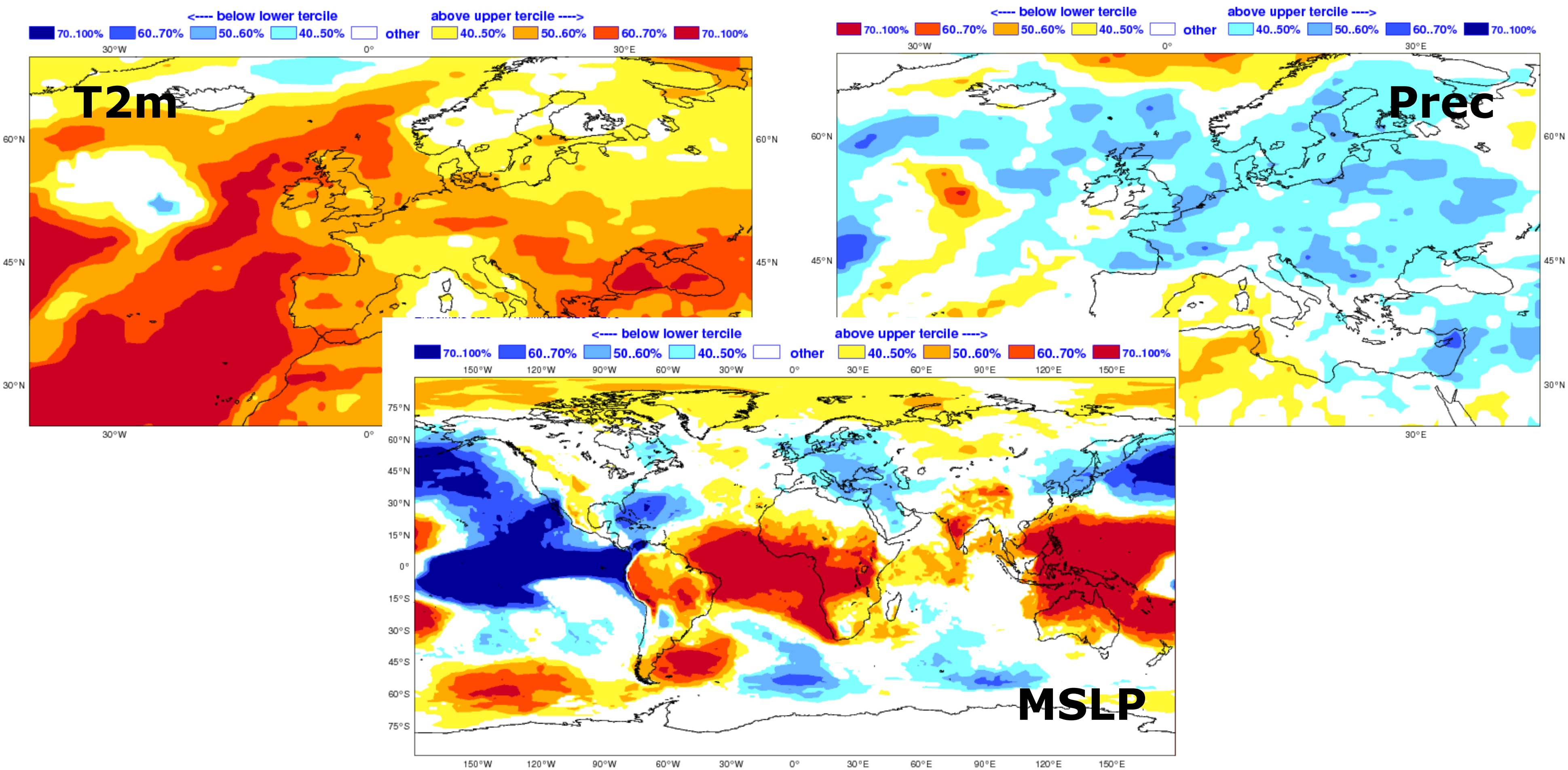


Probabilistic prediction



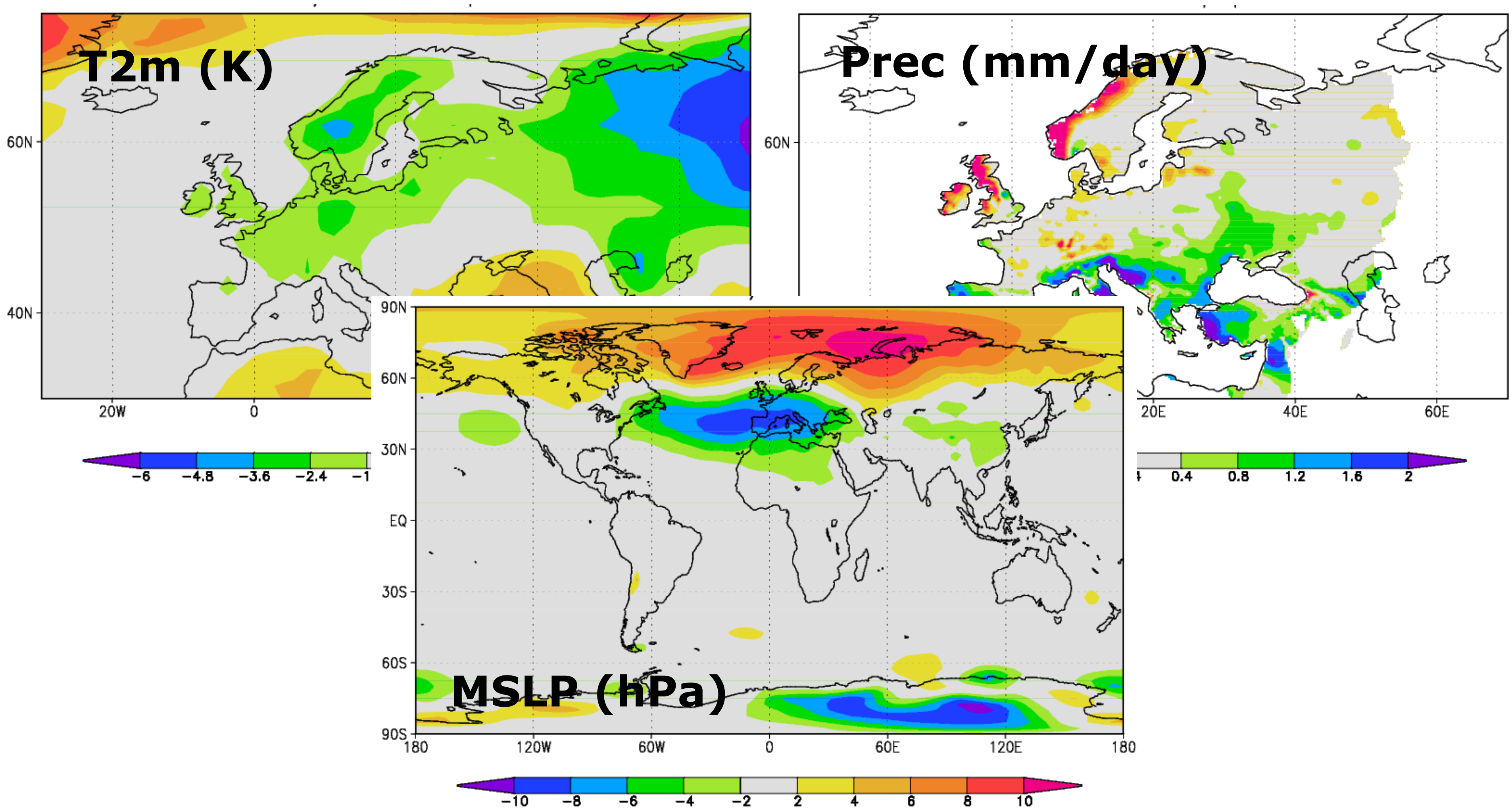
Probabilistic prediction

One-month lead DJF 2009-10 System 3 seasonal forecasts: tercile summary



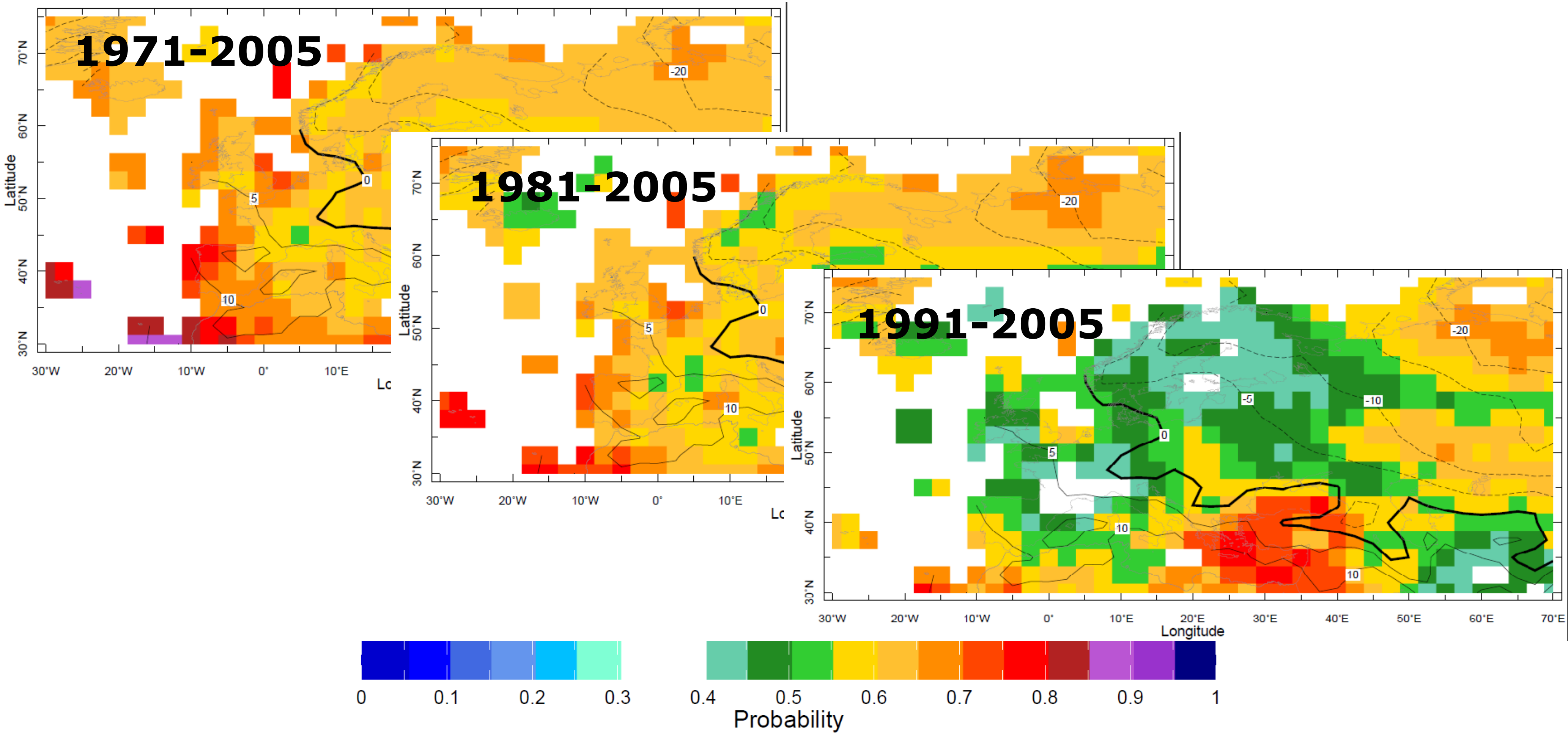
References: what actually happened

DJF 2009-10 seasonal anomalies wrt 1981-2005.



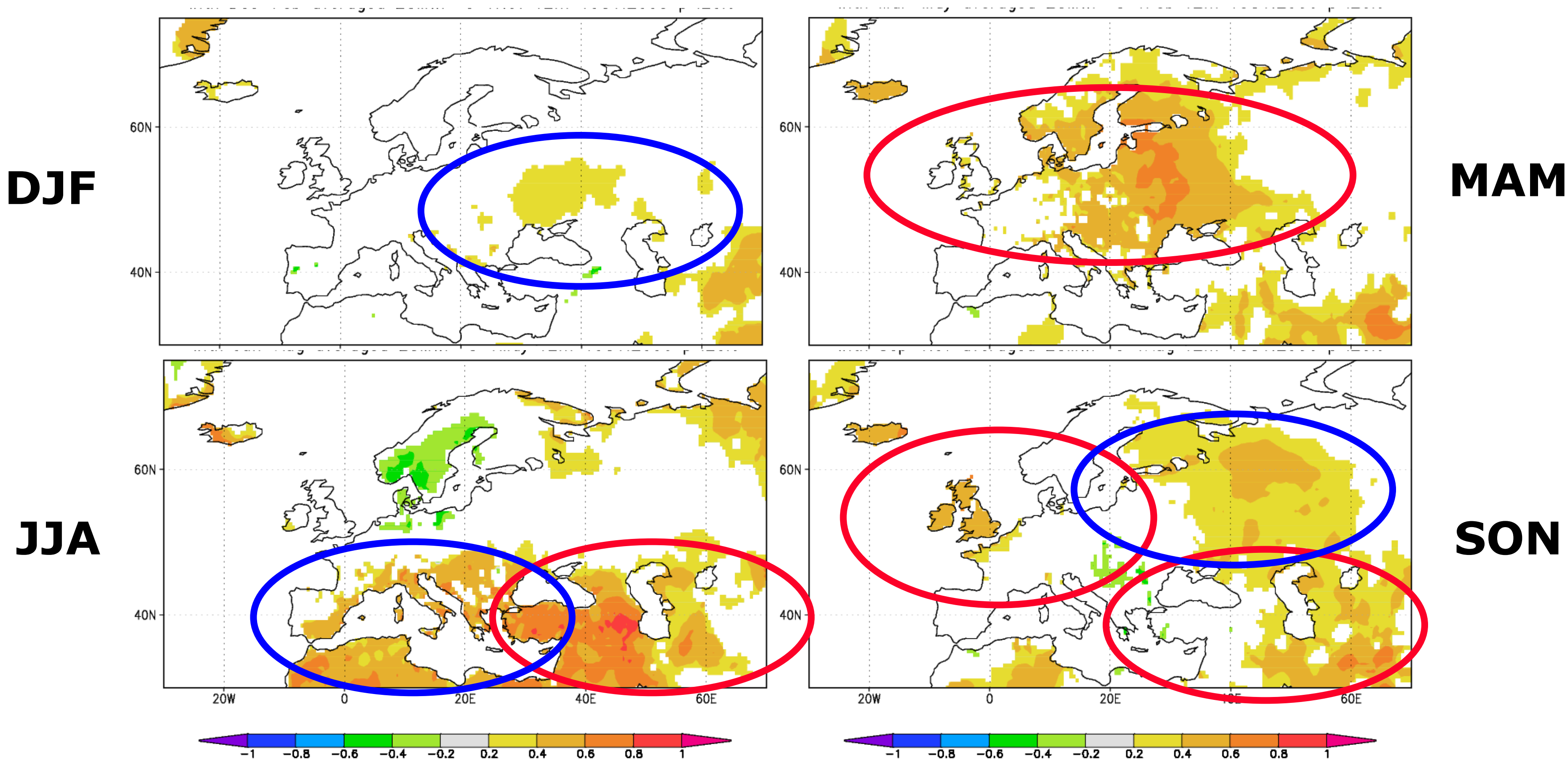
Impact of the reference period

One-month lead DJF 2009-10 IRI (flexible format) temperature forecasts for anom. above the upper tercile



Regional skill: System 4

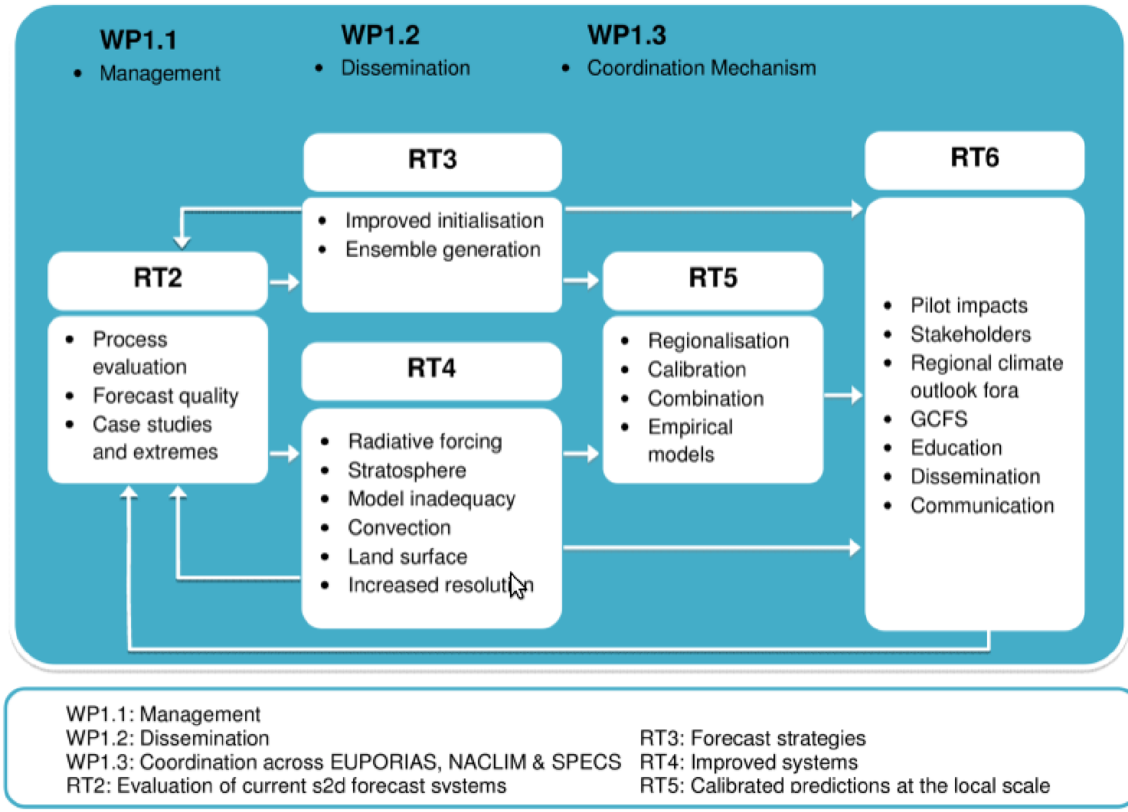
Correlation of System 4 seasonal forecasts of temperature wrt GHCN over 1981-2010. Only values statistically significant with 80% confidence are plotted.



SPECS FP7, overall strategy

SPECS will deliver *a new generation of European climate forecast systems*, *including initialised Earth System Models (ESMs) and efficient regionalisation tools to produce quasi-operational and actionable local climate information over land at seasonal-to-decadal time scales with improved forecast quality and a focus on extreme climate events, and provide an enhanced communication protocol and services to satisfy the climate information needs of a wide range of public and private stakeholders*.

Forecast System	Project Partners
CNRM-CM5	CNRM, CERFACS
EC-Earth	KNMI, SMHI, IC3, ENEA
IFS/NEMO	ECMWF, UOXF
IPSL-CM5	CNRS
MPI-ESM	MPG, UniHH
UM	UKMET



SPECS
Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

Summary

- Work on initialisation: initial conditions for all components (including better ocean), better ensemble generation, etc. Link to observational and reanalysis efforts.
- Model improvement: leverage knowledge and resources from modelling at other time scales, drift reduction. More efficient codes and adequate computing resources.
- Calibration and combination: empirical prediction (better use of current benchmarks), local knowledge.
- Forecast quality assessment: scores closer to the user, reliability as a main target, process-based verification.
- Improving many processes: sea ice, projections of volcanic and anthropogenic aerosols, vegetation and land, …
- More sensitivity to the users' needs: going beyond downscaling, better documentation (e.g. use the IPCC language), demonstration of value and outreach.